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Improvement of Left Ventricular Function after Modified Surgical Ventricular Restoration: Good, Better, Best

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ABSTRACT

Background: The techniques of surgical reconstruction of the left ventricle after an anterior myocardial infarction have evolved toward an increasingly physiologic restoration of ventricular shape and volume, with increasing attention being paid to the multilayered structure of myocardial fibers.

Methods: We describe the case of a patient who underwent operation with a new technique of endoventricular patch restoration surgery, which was aimed at rebuilding the physiologic shape and volume of the left ventricle, with special care taken to realign the orientation of myocardial fibers at the site of the surgical suture on the patch. The case was studied preoperatively and postoperatively via a complete echocardiographic assessment, included 2-dimensional speckle tracking imaging for the study of apical rotation and ventricular torsion.

Results: All geometric and functional parameters were improved at the early and late postoperative evaluations. The left ventricular shape, diameters, and volumes were restored to near-normal values. Apical rotation was improved, both immediately after the surgical procedure and at the late follow-up, with the normal systolic counterclockwise movement and the small clockwise rotation during isovolumic contraction having been restored—signs of normal fiber disposition. As a consequence, torsion of the ventricle was restored, given that the basal rotation remained the same as before the operation.

Conclusions: The beneficial restoration of apical rotation and left ventricular torsion is indirect evidence that our new technique can effectively realign myocardial fibers in a near-normal setting and thereby optimize all aspects of left ventricular performance.

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INTRODUCTION

Surgery for anterior restoration of the left ventricle in the setting of ischemic cardiomyopathy has evolved over the years from linear closure of large aneurysms to the present geometric reconstruction with an endoventricular patch. The circular patch used in the original reconstruction of the residual tissue gap has been replaced by an oval-shaped patch, which ensures a better ventricular shape and volume. Pioneering studies of the 3-dimensional structure of the left ventricular wall [Torrent-Guasp 2005] renewed an appreciation of the orientation of the interlaced myocardial fibers as a key component of normal function.

We developed a new surgical technique of anterior ventricular restoration with the aim of resetting the orientation of residual myocardial fibers to a near-physiologic disposition. We achieved this goal thanks to the use of a very narrow patch (a strip patch) and to a suturing technique for rebuilding the contiguity and orientation of residual fibers [Cirillo 2008]. We present a case of ischemic cardiomyopathy in which our new technique was able to restore major determinants of normal left ventricular function, including apical rotation and left ventricular torsion.

CASE REPORT

A 73-year-old female patient, FMC, with a history of dyspnea and asthenia received a diagnosis of anterior myocardial infarction with aneurysmatic evolution in 2000. A coronary angiography evaluation showed occlusion of the left anterior descending artery (LAD). The patient followed medical therapy. In February 2006, she was admitted to our hospital for pulmonary edema, heart failure, and severe left ventricular dysfunction. A second coronary angiography examination confirmed 2-vessel disease (the LAD and the right coronary artery). The patient was scheduled for surgical anterior ventricular restoration and coronary revascularization.

Preoperative Assessment

Table 1 and Video 1 (online) summarize the results of the preoperative echocardiographic assessment. The demonstration of

Echocardiographic Data*

	Preoperative	Early Postoperative	Late Postoperative
EDD, mm	69	45	44
ESD, mm	57	37	31
Apical diameter, mm†	54	16	15
LLD, mm	79	65	67
LLS, mm	79	58	58
EDV, mL	134	97	52
EDVI, mL/m^2	91	67	36
ESV, mL	106	44	25
ESVI, mL/m^2	72	30	18
EF, %	21	54	52

*The patient's body surface area was 1.47 m^2 before the operation and 1.44 m^2 after the operation. EDD indicates end-diastolic diameter; ESD, end-systolic diameter; LLD, diastolic longitudinal length; LLS, systolic longitudinal length; EDV, end-diastolic volume (biplane); EDVI, end-diastolic volume index; ESV, end-systolic volume (biplane); ESVI, end-systolic volume index; EF, ejection fraction (biplane).

†Internal diastolic diameter 2 cm above the ventricular apex.

anterior, apical, and septal necrosis at delay enhancement in magnetic resonance imaging confirmed the left ventricular dysfunction.

A 2-dimensional speckle tracking echocardiography evaluation [Helle-Valle 2005; Takeuchi 2007] (Vivid 7, EchoPac Dimension; GE Healthcare, Piscataway, NJ, USA) revealed complete absence of apical rotation of the left ventricle, which was due to the loss of contracting muscle and the apex geometry, and the absence of any of the characteristics of the normal counterclockwise systolic wringing movement (Figure 1, Video 2 online). The basal rotation was well preserved, but systolic torsion was overridden by the absence of apical rotation. The base and apex rotated in the same clockwise direction.

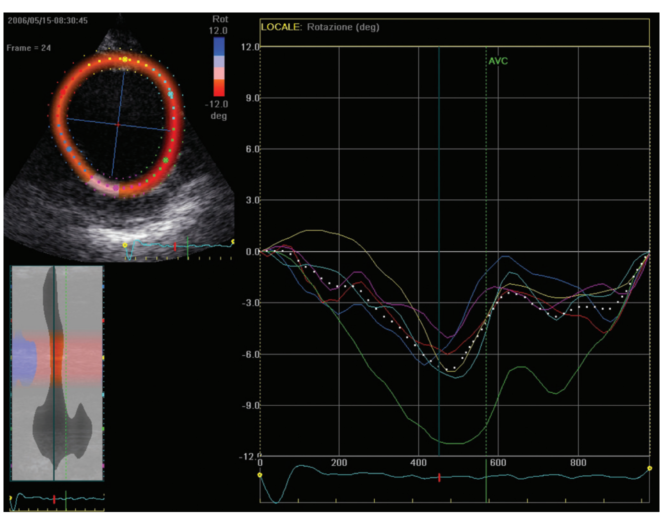

Figure 1. Left ventricular systolic-rotation movement studied by 2-dimensional speckle tracking echocardiography. Short-axis apical level, 4 days before the surgical procedure.

Surgical Procedure

On May 19, 2006, the patient underwent operation by means of a modified surgical anterior ventricular restoration, with the aim of resetting the orientation of the residual myocardial fibers to a near-physiologic disposition. This novel technique is based on several lines of evidence indicating that myofiber orientation in the thickness of the residual normal myocardium is not changed and that the transmural courses of the fiber-orientation angles near infarct zones are similar to those of the normal myocardium [Lutgens 1999; Walker 2005]. The aim of the technique is to reorient normal residual myocardial fibers to a near-normal disposition by means of a strip-shaped patch (in this case glutaraldehyde-fixed autologous pericardium, 1 × 7 cm [sutured dimensions]) and a specific suturing technique [Cirillo 2008].

The restoration technique did not differ from that of the current state of the art, except for 3 specific characteristics:

1. The Fontan purse-string was not used to avoid a nonphysiologic circular arrangement of residual fibers.
2. The strip-shaped patch has a short axis narrower than currently used patches and a long axis tailored to be proportional to the length of the septal necrosis; both ends of the patch are arrow-shaped.
3. The patch is sutured asymmetrically. Along the inferior septum, the suture reflects the complete equivalence between the length of the patch and the border of normal myocardium. Along the lateral wall, the suture shrinks the dilated border line of the normal myocardium to the shorter patch rim, and by so doing, we redirect the fiber orientation toward a more anatomic disposition.

The upper end of the patch is secured at the top end of the septal fibrosis near the aortic valve, and the lower end rebuilds the ventricular apex (Figure 2).

The narrow patch replaces all of the necrotic tissue, and the suture attempts to restore the fiber orientation to a normal helicoidal disposition, compensating for the spacing created by necrosis.

We carried out concomitant complete coronary revascularization (single venous graft on the LAD and sequential grafting on the acute marginal and posterior descending arteries). The postoperative course was uneventful; the patient is currently in New York Heart Association class I.

Postoperative Assessment

Parameter values in the early postoperative period (11 days after surgery) are presented in Table 1, and the restored left ventricular shape and function are evident in Video 3 (online). A better apical rotation is apparent (Figure 3, Video 4 online), with a maximum rotation angle of approximately 3°.

Table 1 also summarizes parameter values in the late postoperative period (17 months after surgery). The steady improvement in results with respect to ventricular shape and function are evident in Video 5 (online). The rotation of the apex has improved significantly, with the maximum rotation angle having increased to approximately 8°. The myocardial

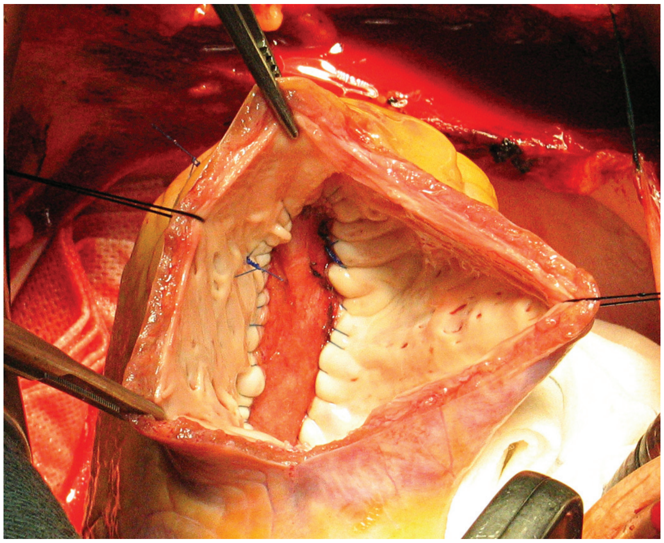

Figure 2. Surgical view from the head of patient at the end of implantation of the endoventricular patch. New apex is at the top; the necrotic septum and the anterior wall are at the right. Note the closeness of the still-normal myocardium and the small residual akinesia.

segments have synchronized, and the small clockwise rotation during isovolumic contraction has been renewed (Figure 4, Video 6 online). Sonomicrometric studies have confirmed this specific characteristic of ventricular rotation, and this result might be attributed to activation of subendocardial fibers (right-handed helix) earlier than subepicardial fibers. As a consequence, given that the basal rotation remained the same as before the operation, the left ventricular torsion was restored compared with the preoperative status and was clearly improved compared with that seen in the early postoperative evaluation. The maximum torsion angle was approximately 12° (Figure 5).

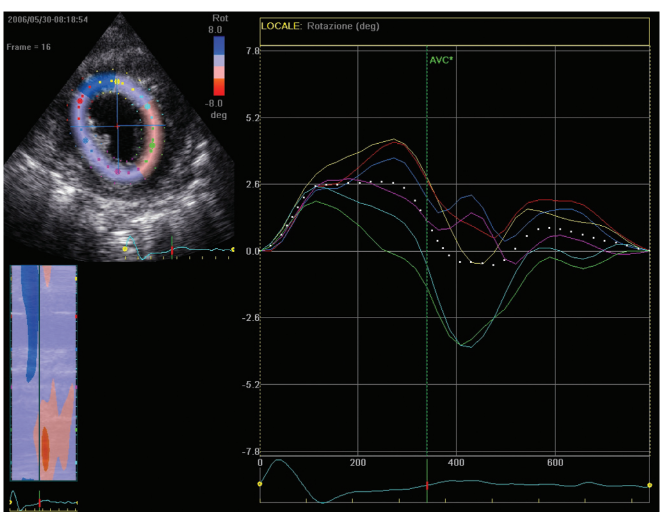

Figure 3. Left ventricular systolic-rotation movement studied by 2-dimensional speckle tracking echocardiography. Short-axis apical level, 11 days after the modified surgical anterior ventricular restoration aimed at realigning residual myocardial fibers.

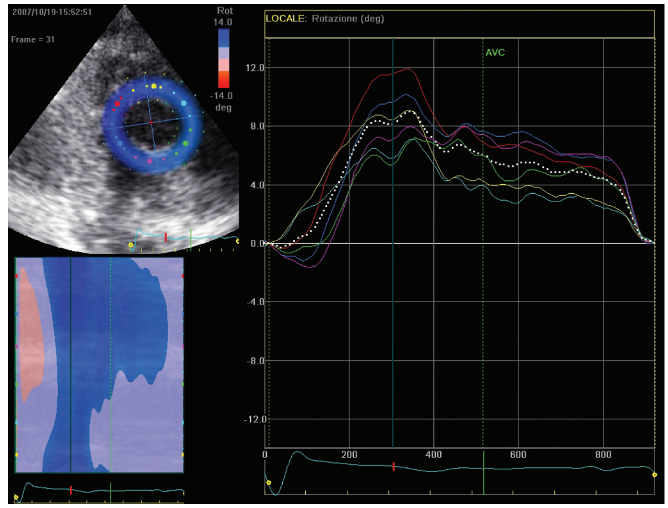

Figure 4. Left ventricular systolic-rotation movement studied by 2-dimensional speckle tracking echocardiography. Short-axis apical level, 17 months after the surgical procedure.

DISCUSSION

The reported case is a clear example of how much we can restore left ventricular function to a near-normal state when we pay attention to all aspects of left ventricular anatomy, geometry, and physiology. The described surgical procedure aims to approach the residual myocardium to correct the deficiency in the myocardial continuum (the main requirement for a normal global function) and to redirect fiber orientation. Our method differs from current restoration techniques in that it adapts the surgical suture to the disarrangement of the residual myocardium, fitting it to produce a more physiologic arrangement of the fibers. The shape of the patch forces functioning fibers to be close together, leaving a smaller akinetic part.

Chamber geometry and fiber rearrangement are key in the surgical treatment of ischemic cardiomyopathy. Modern echocar-

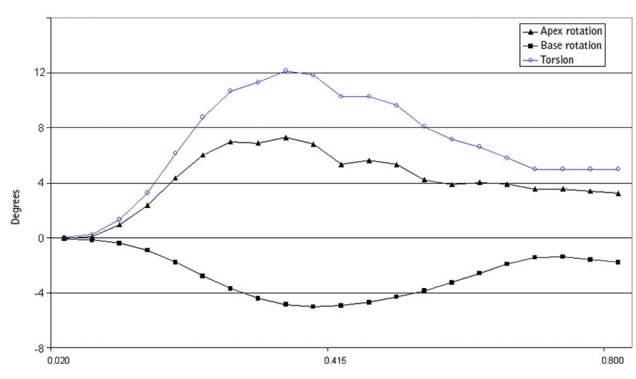

Figure 5. Left ventricular (LV) torsion at late follow-up. Restoration of apical rotation and the unchanged basal rotation generate a nearly normal twist of the LV (highest value, 12°). Torsion was calculated as the net difference between the apical and basal rotations, in degrees (apical LV rotation – basal LV rotation).

diographic tools allow us to monitor surgical results and to improve our evaluation of the entire left ventricular function, adding important functional parameters to the standard evaluation of surgical outcomes. The attempt to realign residual myocardial fibers completes a multifactorial approach to surgical ventricular restoration. In particular, the renewal of apical rotation and global torsion represents a new parameter for evaluating this surgical treatment. Torsion is a sensitive marker of ventricular function in physiologic and pathologic settings and appears to be a critical link between systole and diastole, with elastic energy being stored during systole and then released with sudden untwisting during isovolumic relaxation. It is well known that the twisting motion of the left ventricle about its long axis results from the contraction of the opposite, obliquely oriented epicardial and endocardial fibers [Spotnitz 2000]. The renewal of this motion could be considered indirect evidence of the fibers' realignment, which starts after the surgical correction of the mechanical properties and continues owing to a positive remodeling process over time. To our knowledge, an improvement in ventricular torsion, although postulated, has never before been demonstrated for any technique of ventricular restoration [Setser 2003, 2007]. These findings could increase the potential for repairing a failing heart and guaranteeing a lasting surgical outcome.

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